

PERFORMANCE EVALUATION OF MANUAL AND MECHANICAL RICE PUFFING MACHINES

BASAVARAJ¹, RAVITEJA. G², SHRINIVAS. D³, RAMAPPA. K. T⁴ & SHARANAGOUDA. H⁵

¹Teaching Associate, Department of Farm Machinery and Power, College of Agricultural Engineering,
Professor Jayashankar Telangana State Agricultural University, Telangana, India

²M.Tech, Department of Processing and Food Engineering, CTAE, MPUAT, Udaipur, Rajasthan, India

³M.Tech, Department of Agricultural Engineering, UAS, GKVK, Bangalore, Karnataka, India

^{4,5}Assistant Professor, Department of Processing and Food Engineering, College of Agricultural Engineering,
University of Agricultural Sciences, Raichur, Karnataka, India

ABSTRACT

India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. Rice is India's pre-eminent crop and is the staple food of the people of the eastern and southern parts of the country. India is one of the leading producers of this crop. In order to understand the rice puffing technology and to know how the different parameters influencing the puffed rice making process, the present investigation "Performance Evaluation of Manual and Mechanical Rice Puffing Methods" has been under taken in the Dept. Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur during the year 2012-13. In both the cases the rice was pre-treated with hydro-thermal treatment after the treated rice exposed to 240-250°C for actual puffing operation. The capacities of manual and mechanical puffing machines were 50 kg/hr and 100 kg/hr, respectively. It was found that no significant difference was noticed with respect to taste. The expansion volume of puffed rice soaked in salt solution was more as compared to rice soaked in tap water. The expansion volume of puffed rice was higher when the moisture content increased from 10 to 13%, but was lower when the moisture content was 16 and 19 %. As the length width-width ratio increases, the expansion ratio also increases. Higher the amylase content in the rice influenced the higher expansion ratio. Manual and mechanical methods were about 2 months with respect to crispiness and cooking quality is concerned. The total cost of operation per hour for manual and mechanical rice puffing machines were found that 1356.85Rs and 2754.06Rs, respectively.

KEYWORDS: Puffed Rice, Parboiling, Expansion Ratio, Mechanical Puffing Method and BC Ratio

INTRODUCTION

India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. Rice is India's pre-eminent crop and is the staple food of the people of the eastern and southern parts of the country.

Rice is one of the chief grains of India. Moreover, this country has the largest area under rice cultivation, as it is one of the principal food crops. It is in fact the dominant crop of the country. India is one of the leading producers of this crop. Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. Rice is

mainly grown in rain fed areas that receive heavy annual rainfall. That is why it is fundamentally a kharif crop in India. It demands temperature of around 25 degree Celsius and above and rainfall of more than 100 cm. Rice is also grown through irrigation in those areas that receives comparatively less rainfall. Rice is the staple food of eastern and southern parts of India. In 2009-10, total rice production in India amounted to 89.13 million tonnes, which was much less than production of previous year, 99.18 million tonnes.

Rice is a major source of energy and an important source of protein. It also contains substantial amounts of zinc and niacin. On the other hand, it is low in calcium, iron, thiamine and riboflavin and has virtually no beta-carotene (Vitamin A). It is noteworthy that the highest the degree of polishing, the lowest the level of proteins, vitamins and minerals in the final product (Gopalan et al., 1971).

The processing of puffed rice from paddy is traditionally takes about 6 days. Some of the tasks, particularly manual roasting of paddy and immersing in water, mixing the ingredients with milled rice and stirring the rice in roaster pan for uniform heating are highly labour intensive operations. Complete mechanization of the process has not yet been undertaken. Many of the rice puffing units are of the traditional type and are inefficient. Modern rice puffing machines are having high capacity and are capital intensive, although efficient.

Traditional puffed rice called muri (sometimes spelled mouri) is made by heating rice in a sand-filled oven. Muri is to rice as popcorn is to corn. The processing involved makes rice less perishable. Mandakki is a staple food in many parts of Rayalaseema, Karnataka, Odisha, Tripura, West Bengal and Bangladesh. Jhalmuri or Masalemandakki is a very popular preparation made from mandakki (muri). Puffed rice is formed by the reaction of both starch and moisture when heated within the shell of the grain. Unlike popcorn, rice kernels are naturally lacking in moisture and must first be conditioned with steam. Puffed rice can be created by heating the steam-conditioned kernels either with oil or in an oven. Rice puffed in this way is crisp, and known as "crisped rice". Oven-crisped rice is used to produce the rice krispies breakfast cereal as well as the crisped rice used in Lion Bars, Nestlé Crunch, krackel, and similar chocolate bars.

Since marketing of products is more remunerative than raw commodities, farmer processor linkages are needed to add value as per demands of the consumers. There is a great scope of developing some of our traditional food items from cereals. Appropriate and cost-effective processing and packaging technology for these items is needed to ensure safety and prolonged shelf life.

In order to understand the rice puffing technology and to know how the different parameters influencing the puffed rice making process "Performance Evaluation of Manual and Mechanical Rice Puffing Machines" undertook.

Hsiehet al. (1990) reported that the best operational conditions for puffing dent corn grits with a rice cake machine were 14% grit moisture, 215°C and 9 sec. Salting and steaming, low pH soaking medium, larger corn grit sizes, 2% glycerine, and 2% corn oil tended to increase puffed volume of the corn cakes. Smaller grit sizes, 3% alcohol and high pH soaking medium had negative effects on corn cake volume. Acid-modification of corn starch, 1% or 3% corn oil, and up to 10% sugar had no effect.

Azlin (2005) studied the composite mix of Okara as the by-product of soymilk and tofu during the snack food development. It is cheap and nutritious having great potential to be applied in healthy snack foods. In this study, a puffed soy/rice cake product was developed and consumer tests were conducted. Main plot was okra pellets and parboiled rice.

MATERIALS AND METHODS

The manual and mechanical methods of rice puffing methods are considered for evaluation. Some of the factors considered for the evaluation viz., Operational parameter, conditioning of rice, operation speed of stirrer, machine capacity, pre-treatment conditions, labour requirement, drudgery of operation, environmental safety condition, Safety of operation, efficiency of puffing operation etc.

Conditioning of Rice

In manual method of rice puffing, the addition of salt solution will be added in twice, i.e pre-heating time and after roasting before puffing operation. But in case of mechanical rice puffing, salt solution will be added only once i.e. pre-heating in the cylinder.

Operational Speed

The operational speed is only the speed of stirrer used in all the pans for stirring of rice during pre-heating as well as during puffing rice preparation. In case of mechanical method of puffing the operational speed considered was the rotation of cylinder.

Machine Capacity

In manual puffing method, the process of puffing operation is batch type and sequence of different operations. In case of mechanical method, after treating and conditioning, final puffed rice were collected.

Pre- Treatment Conditions

In manual method of puffing pre-heating is done in four pans in simultaneously and later the pre-heated rice will be puffed in another pan containing sand. But in case of mechanical method, pre-heating is done two times in rotating cylinder having sand.

Labor Requirement

For puffing operation in manual method, 2 labours are engaged for completion of all activities such as conditioning, roasting, and addition of salt solution, puffing and bagging. In case of mechanical methods 2 labours are engaged for completion of all puffing activities.

Drudgery of Operation

As per the labour opinion the operations performed in manual method such as pre-heating puffing, addition of salt solution will be done in exposed to heat. These operations should be performed by sitting close to the heating source. During final puffing operation in final pan one has to raise the stirrer for taking out puffed rice and it needs much energy that may leads to fatigue. In mechanical method all these operations are necessary, but no close operation with respect to heat is needed. All these operations are carried out in the rotating cylinder which is fixed well inside the walls.

Environmental Safety Conditions

In manual method, for puffing operation fuel used as saw dust and paddy husk. The un-burnt gases are exposed to environment through chimney. In mechanical method also the burnt gases are blown to the environment through chimney

provided at the top of the combustion chamber. In this method, the fuels are forced to the combustion chamber by using centrifugal pump. This may leads to considerable pollution in and around the puffing plant.

Safety of Operation

In manual method one has to associate closely with the puffing machine and susceptible to injury if proper attention is not given. That too while working around pan one needs to be very care full as the pan temperature raises to around 90 °C. Also the stirrer should be raised during final operation of puffing where the operator needs to be care full. Again there is a chance of high heated sand overfilling if properly not handled.



Figure 1: Mechanical Puffing Machine



Figure 2: Manual Puffing Machine

Efficiency of Puffing Operation

Capability of the puffing unit to produce a specific outcome effectively with minimum amount or quantity of waste, expenses. Efficiency is ratio of output to input. The factors affecting the efficiency of puffing machines are as follows.

- Production of puffed rice
- Machine durability

Cost of Operation

Cost of operation of for manual and mechanical rice puffing includes fixed and variable cost. Under fixed cost some of the parameters considered are investment, depreciation, and housing. For variable cost considered for both the methods are raw materials, power consumption, labour and repair and maintenance.

FIXED COSTS

Initial Investment

The initial investment required for setting up of manual rice puffing plant includes fixing of pans below the ground and making the compartment air tight, arranging stirrers for all the pans through external frame, power source for power transmission and providing heating source.

In mechanical method, the purchase of puffing machine (cylinder cum power source), providing brick walls around the cylinder, arrangement of fuel supply system, arranging below ground level furnace for heating source.

Depreciation Cost

Depreciation is a largest single item in the fixed cost and it refers to the loss in the value with the passing of time. Depreciation of both the machines was calculated by using following equation.

$$D = \frac{C - S}{L \times H} \text{ Rs/h}$$

Where,

- D = Depreciation per hour
- C = Capital investment
- S = Salvage value, 10% of capital investment
- L = Life of machine in years
- H = No. working hours in year

Interest

Interest on investment is calculated using the following equation

$$\text{Interest, Rs} = I = \frac{C - S}{2} \times \frac{i}{H} \text{ Rs/h}$$

Where,

- I = Interest per hour
- i = Per cent rate of interest per year

Housing and Insurance

In this case the space requirement for setting up of puffing unit (5 pans), underground furnace for heating source, raw material keeping, pre-treatment of raw rice and storage for puffed rice. In mechanical puffing unit the space requirement is similar for all other operations except puffing unit (cylinder).

VARIABLE COST

Raw Materials

The raw materials required for puffing operation for both the methods are parboiled rice, saw dust/husk, salt, cooking soda, sand and poly bags were procured from local market.

Power Requirement

For machine operation, electrical power is used in both the methods of puffing units. But for heat treatment biomass fuels such as saw-dust/husk is used during puffing.

Labour Requirement

For both the methods 2 labours are used to perform all the unit operations of puffing technology.

Repair and Maintenance

For both the methods 10 % of the investment is considered for repair and maintenance.

Total Cost of Production

The total cost of puffed rice production will be calculated by adding both fixed cost and variable cost.

Total cost= Fixed cost +Operating cost

Puffing Quality

The parameters considered for computation of puffing quality of puffed rice are taste, expansion ratio, crispiness, product hygienic condition and storage life.

Taste

Taste is sensation produced when a substance in mouth reacts with a receptors of taste buds. Here the taste refers to mouth feel of a product with respect to saltiness or sweetness.

Expansion Ratio

It refers to the process of expanding the quality or increase in volume of working as a steam in a cylinder. The expansion ratio is determined by measuring the bulk volume of 20 g of the original parboiled rice and that of the resulting expanded rice in 50 ml and 200 ml graduated measuring cylinder.

Crispiness

Crispiness is the gustatory sensation of brittleness in mouth such that the food item shatters immediately upon masticating. The crispiness of puffed rice will be found out by textural analyzer.

Product Hygienic Condition

It is mainly a quality parameter considered to know the condition of its cleanliness. This factor is analyzed by soaking the puffed rice and corresponding dissolved particles in the soaked water.

Storage Life

Storage life of puffed rice is the time up to which the product will be stored without deterioration with respect to keeping quality and overall acceptability.

RESULTS AND DISCUSSIONS**Operational Parameters****Operational Speed**

Speed of the stirrer in manual puffing machine is 45-60 rpm for 7-10 sec during puffing of rice which is done in separate pan. But in the other 4 pans, stirrers will be run continuously till the desired temperature of conditioned rice. In mechanical puffing machine, cylinder rpm is fixed at 20 and it accommodates for both conditioning as well as puffing of rice. Stirring is mainly to induce uniform heating as well as to avoid over heating/burning of rice.

Capacity

As in manual rice puffing operation, the pre puffing operations such as conditioning and pre heat treatment done with manual labour, its capacity was found to be 50 kg/hr whereas, in case of mechanical machine all these operations are done within the same cylinder, so that the capacity of machine was worked out as 100 kg/hr.

Pre- Treatment Conditions

In both the cases the rice was pre-treated with hydro-thermal treatment after the treated rice exposed to 240-250°C for actual puffing operation. The purpose of hydro thermal treatment is to increase the humidity inside the kernel center and formation of dry solid layer on the kernel surface. This creates miniature pressure vessel that can work as puffing gun i.e. inside the kernel water over heats and during rupture of surface expansion occurs. Degree of milling also has the considerable effect on the puffing quality of rice. In principle the pre-treatment operations performed for both the methods of puffing operations are similar. The purpose of these treatments is to create necessary environment inside the kernel so as to get puffed rice.

Labour Requirement

The labour requirement for the both the methods i.e 2 in number, but the output obtained by utilizing the labour force is different. It is evident from the study that, the capacity of the manual rice puffing machine is 50 kg/hr and for mechanical puffing machine it is 100 kg/hr.

Drudgery

As per the survey conducted with the people involved in the rice puffing units, the drudgery involved in the process of puffing of rice in manual puffing machine is quite high. This is due to proximity of working place for manual labour where they have to work very closely with the heated pans which is radiating heat radiation also exposure to very unhygienic external dusty atmosphere. All the operations performed are really difficult one and leads to tired some. The unburnt gases liberated during burning of firehood also create health hazards.

The puffing operations performed in mechanical puffing machine are quite different. Here all the different operations are performed in the cylinder which is close enough to get rid of heat radiations. Again as the capacity of this machine is high, the time taken to complete the puffing operation task is quite less. By this way the drudgery involved in this method is less as compared to manual method. But one noticeable thing in mechanical machine is generation of dust

during puffing operation which is very high due to forced feeding of firewood inside the furnace. This has definitely has some health hazard for the labours involved.

Environmental Safety Conditions

The environmental pollution from puffed rice unit is a result of the lack of pollution control measures such as usage of low-grade hazardous fuels in primitive furnaces. Fuels used in the furnace for puffed rice making are mainly rice husk, saw dust, groundnut shell, and agricultural residues. Sometimes automobile tyres were also used in view of high heat it generates and low cost. Thus, air pollution is the most serious problem in the puffed rice making units in the form of particulate matter, carbon monoxide and other harmful airborne pollutants from tyre burning.

Power Requirement

Power requirement is less (Rs. 4 per hour) for manual working puffing machine as in this case only one motor is in operation as compare to the mechanical rice puffing unit (Rs.8 per hour).

Safety of Operation

During the study, safety of both the puffing operations methods were observed and it is found that in manual operating puffing machine, the following difficult tasks were identified.

- Salt treatment and roasting operations are performed in the open over heated pans where high amount of heat radiations are present. So the operation turned to be difficult and leads to fatigueness to the operators and sometime leads to burning if proper care has not been taken.
- Lifting of stirrer every time before the removal of puffed rice. It is really difficult and needs high concentration otherwise leads to detrimental effect.
- Again there is a possibility of spillage of overheated sand that may leads to burning effect
- Care must be taken during pre-treatment of rice in the pan where sharp stirrers are rotated automatically. So any careless situation leads to injury.

But in mechanical puffing machine all operations are carried in the cylinder that is placed inside the four walls in such a way that, no heat radiation comes out and the cylinder is out of reach of labour. But care must be taken with the rotating pulley for safety of operation.

Efficiency

In manual method the operation production of puffed rice was 80 bags for 5 hours whereas in mechanical method it was 160 bags. The life span of both the machines are almost same i.e. around 10 years. The quality of puffed rice obtained with both methods are almost similar.

Cost of Operation of Manual Puffing Machine

The total cost of operation involved in the production of puffed rice from both manual and mechanical puffing machines are categorized in two ways i.e.

- Fixed cost and
- Variable cost.

The details calculation of fixed and variable cost are shown in Annexure II. The cost of operation is shown in the Table.

Table 1: Cost of Operation for Manual and Mechanical Puffed Rice Methods

Description	Manual	Mechanical
Total cost of operation per hour	1386.87	2754.06
Total puffed rice per hour	16 bags	32 bags
Total cost of puffed rice	1520.00	3040.00
Net profit	133.13	285.94
BC Ratio	1.09	1.10

Puffing Quality

Taste

The general acceptance of consumer for regular usage is considered in respect of taste. It was found that no significant difference was noticed with respect to taste. Taste is mainly characterized by the quantity of salt solution used and the stickiness during mouth feel.

Expansion Ratio

The expansion ratio of the IR 64 was observed as 12.5. The expansion volume of puffed rice soaked in salt solution was more as compared to rice soaked in tap water. The expansion volume of puffed rice was higher when the moisture content increased from 10 to 13%, but was lower when the moisture content was 16 and 19 % (Suchada et al., 2010). Expansion ratio of puffed rice is influenced by the amylase content of rice, salt solution treatment and the length-width ratio. As the length width-width ratio increases, the expansion ratio also increases. Higher the amylase content in the rice influenced the higher expansion ratio.

Product Hygienic Condition

The product hygiene observed for the puffed rice obtained from both the methods were observed. It was found that the dissolved solids obtained after soaking of puffed rice from manual method is less as compared to mechanical method. This may be due to exposure of puffed rice to a high degree of dust generated during pressure feeding of saw-dust in mechanical rice puffing methods.

Storage Life

As per the consumers of puffed rice opinion the storage life prepared from both the methods i.e manual and mechanical methods was about 2 months with respect to crispiness and cooking quality is concerned.

Table 2: Evaluation Parameters of Manual and Mechanical Rice Puffing Machines

Description	Manual	Mechanical
Capacity	200 kg/day	400 kg/day
Labour requirement	2	2
Temperature in puffing	240-250°C	240-250°C
Expansion ratio of rice	11.8	12.5
Storage life	2 months	2 months

CONCLUSIONS

Considering the above parameters conclusion were drawn for the present

- Maximum expansion ratio can be obtained with the rice having maximum length-width ratio.

- The maximum expansion ratio of 12.50 was recorded for puffed rice obtained from mechanical puffing method as compared to manual puffing method (11.8).
- The efficiency of manual rice puffing unit is less than that of mechanical puffing unit.
- The capacity of puffed rice production in manual method is less (200 kg/day) than that of mechanical puffing method (400 kg/day)
- The drudgery involved in the production of puffed rice in manual rice puffing unit is more as compared to mechanical puffing method.
- The net profit (BC ratio) of puffed rice production is more in mechanical puffing unit (1.11) as compared to manual puffing unit (1.09).
- There is no significant difference between the taste and quality of puffed rice obtained from manual and mechanical rice puffing unit.

REFERENCES

1. Gopalan, C, Ramasastri, B.V and Balasubramanian, S.C, (1996), Nutritive Value of Indian Foods. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India.
2. Hsieh, F and Luh, B.S., (1990), Breakfast rice cereals and baby foods. Nostrand Reinhold, NY. pp: **177**
3. Juliano, B. O, (1985). International survey of rice grain quality. Chemical aspects of rice grain quality. IRRI, Los Banos, Philippines, pp. **82-84**.
4. Mohamed, A. A, Ashman, R. B and Kirleis, A. W, (1993). Pericarp Thickness and Other Kernel Physical Characteristics Relate to Microwave Popping Quality of Popcorn. J. Food Sci. **58**:342-346.
5. SuchadaMaisont and Woatthichai Narkrugsa, (2010), Effects of salt, moisture content and microwave power on puffing qualities of puffed rice, Kasetsart J. (Nat. Sci.) **44**:251 - 261 .
6. VenkateshMurth, K, Amit, K, Das and. Raghavarao, K. S. M. S,(1975), Modelling of heat and mass transfer during puffing and popping of grains by fluidization, Department of Food Engineering, Central Food Technological Research Institute, Mysore.